

The Osmotic Pressure of Cane-Sugar
Solutions in the Vicinity of the
Freezing Point of Water.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF
THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY
WITH THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY.

BY

WILLIAM W. HOLLAND.

BALTIMORE

1907

EASTON, PA. :
ESCHENBACH PRINTING COMPANY.
1907.

The Osmotic Pressure of Cane-Sugar
Solutions in the Vicinity of the
Freezing Point of Water.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF
THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY
WITH THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY.

BY

WILLIAM W. HOLLAND.

BALTIMORE

1907



EASTON, PA. :
ESCHENBACH PRINTING COMPANY.
1907.

CONTENTS.

Acknowledgment.....	4
Introduction.....	5
The Control of Temperature Conditions.....	6
The Cell.....	10
The Manometer.....	11
Experimental Part.....	14
Summary of Results	42
Discussion of Loss in Rotation.....	43
Corrections for Inversion and Dilution.....	47
Conclusions	50
Biography.....	53

ACKNOWLEDGMENT.

The author desires to express his gratitude to President Remsen, Professor Morse, Professor Jones, Professor Renouf, Dr. Tingle and Dr. Swartz for instruction in the lecture room and in the laboratory. Also to Dr. Frazer and Dr. Acree for advice and assistance.

Especially does he wish to express his sincere gratitude and thanks to Professor Morse, under whose direction this investigation has been pursued, and to Professor Jones for their very kind interest and invaluable assistance in his behalf.

The Osmotic Pressure of Cane-Sugar Solutions in the Vicinity of the Freezing Point of Water.

INTRODUCTION.

The previous work on osmotic pressure in this laboratory has been carried out at temperatures ranging between 20° and 24° C. From results obtained by Pfeffer,¹ Van't Hoff² was led to put forward the hypothesis that the osmotic pressure of a solution of cane-sugar is exactly equal to the gas-pressure of a gas having the same number of parts in a given volume, temperature being the same in both cases. This hypothesis was supported by the data tabulated below, which were presented in Van't Hoff's paper.³

Temperature.	Osmotic pressure of cane sugar.	Gas pressure of hydrogen gas.
6°.8	0.664	0.665
13°.07	0.691	0.681
15°.5	0.684	0.686
36°.0	0.746	0.735

At these temperatures the osmotic pressure of dilute solutions appears to obey the gas laws.

Results obtained by Morse and Frazer⁴, published under the title "The Osmotic Pressure and Freezing Points of Solutions of Cane-Sugar," show that the osmotic pressure of solutions, ranging in concentration from 0.05 to 1.00 gram-molecular weight of sugar in 1000 grams of water, obeys the hypothesis of Van't Hoff, provided the standard for the gas volume is the volume of the solvent in the pure state. This change from the volume-normal to the weight-normal basis,

¹ Osmotische Untersuchungen (1877).

² Ztschr. phys. Chem., 1, 481 (1887).

³ Ibid., 1, 493 (1887).

⁴ Am. Chem. J., 34, 93 (1905).

by Morse and Frazer, amounts to an automatic correction for the volume of the dissolved substance, and makes the law, developed by Van't Hoff for dilute solutions, also applicable to concentrated ones. The conclusion reached by the authors, above mentioned, regarding the magnitude of the osmotic pressure of cane sugar solutions was expressed as follows: "*Cane sugar, dissolved in water, exerts an osmotic pressure equal to that which it would exert if it were gasified at the same temperature and the volume of the gas were reduced to that of the solvent in the pure state. In other words, dissolved cane-sugar exerts an osmotic pressure throughout the larger volume of the solution equal to that which, as a gas, it would exert if confined to the smaller volume of the pure solvent.*"

With the above facts in mind it was thought advisable to measure the osmotic pressure of solutions at low temperatures in order to ascertain whether, at these temperatures, they would obey or deviate from the calculated gas pressures as the lowering of the freezing points of cane sugar solution have been found to deviate from the calculated values. The temperatures at which the following series of measurements were made were near that of the freezing point of water.

The Control of the Temperature Conditions.

The bath¹ is the same as that employed for the measurement of osmotic pressure at higher temperatures, with additional compartments for holding ice. The following description of this bath will be given: It consists of a rectangular wooden box 1.23 meters long, 0.45 meter wide and 0.65 meter deep. It is lined with copper and has a capacity of about 300 liters. This box is surrounded by one of larger size, the distance between the walls of the two being everywhere not less than 75 mm. This intervening space is tightly packed with hair. Above this bath is a double-walled air compartment, 0.5 meter high, a width equal to that of the bath and extending over about three-fourths of the length of the same, leaving room at one end for the machinery² used to keep the water and air in the bath in constant circu-

¹ Am. Chem. J., 36, 1.

² Ibid., 36, 3.

lation. It is provided with a top, hinged at the back, and is opened by means of a cord running over pulleys attached to the ceiling. The front is provided with a mirror plate-glass window, hinged at the bottom. This window is covered by a heavy pad of hair which is divided into sections, different sections being taken down, according to the portion of the interior of the bath which is to be brought into view. The entire bath is surrounded by extra heavy pads of hair, which may be removed at will. Furthermore, all the cracks and joints of the bath are covered with surgeon's tape and then shellaced. After the bath has been opened for the introduction or removal of a cell and manometer or for the purpose of putting in more ice, the crevices of the top and window plate-glass are again covered with surgeon's tape in order to render it as nearly air-tight as possible.

For the circulation of the water in the tank the following arrangement is provided: A lead pipe of 30 mm. internal diameter, joined to a larger brass pipe at its upper end and terminating just below the surface of the water, runs down one end of the tank and along its bottom, to the other end. Another pipe, arranged in much the same way, though terminating above the surface of the water, passes down the end of the tank to the bottom, where it divides and passes to either corner of the other end of the tank, where it rises and terminates near the top of the air compartment. Operating within the brass portion of the water pipe is a screw propeller, drawing the water from the bottom of the far end of the tank and delivering it at the surface beneath the machinery, and in the air shaft a fan rotates and draws the warmer air from the upper part of the compartment and delivers it at the surface of the other end of the tank. This arrangement for circulating air through pipes immersed below the water was designed with a view of maintaining both the air and water at as nearly the same temperature as possible.

The machinery¹ by which the pump and fan are operated is situated above the tank and outside of the air compartment. The propeller and fan are rotated by means of two

¹ Am. Chem. J., 36, 5.

flat discs, faced with leather, mounted on a horizontal shaft connected by a belt with the motor below. The speed of the fan and propeller can be varied through wide ranges. The most satisfactory speeds have been found to be about 800 rotations per minute for the propeller and 2500 for the air fan. All this machinery is accurately constructed and runs smoothly for long periods with little attention.

The bath, with the cathetometer and standard meter scale, is mounted upon the firmest supports which are set into the thickest brick walls of the building.

The following modifications were made for obtaining the low temperatures: A nice box of galvanized iron was suspended in each end of the bath. These boxes consist of superimposed and readily separated sections. The lowest of these extended from near the bottom of the tank to a short distance above the surface of the water, and they were held in their positions by lugs riveted to the sides which rested upon the top of the tank. They were provided with perforated bottoms, and also a little below the water line perforations were made in order to insure a free circulation of the water about the ice. The higher sections of the boxes are without bottoms, and served merely as lateral retainers for the ice. Each box extended upward in the air space to a height somewhat above the tops of the manometers, and each contained, when filled, about 75 kilograms of ice. Above the space between the boxes and resting on their adjacent rims, was a galvanized iron tray, as wide as the tank, which was likewise filled with ice. This was put in place after the cells were introduced into the bath. Still further provisions for cooling the air space above the water was made by placing a narrow ice box in the rear of the bath behind the manometers.

In order to maintain a constant level of the water in the bath, an automatic siphon was employed. This consisted of a siphon with limbs of equal length and upturned ends. The horizontal portion passed through one of the end walls of the bath, leaving one of the curved ends of the tube submerged in the water in the tank and the other suspended over a waste pipe on the outside of the tank, leading to a large tub, which

was graduated to pounds. The level of the water in the tub was indicated by another automatic siphon, registering on the graduated scale. At any time readings could be taken on this scale, showing how many pounds of ice had melted in any given period of time. On an average about 8 to 10 kilograms of ice melted daily.

The bath was opened as seldom as possible, usually only for the introduction of a cell and manometer,, and at such times more ice would be added after that in the boxes had been well packed down. The ice was broken up into pieces about the size of one's fist. The windows of the room in which the bath is located were always kept open in order to get the benefit of the outside temperature. Most of the measurements were carried out in the winter months.

The cell, while a measurement is in progress, rests about 18 inches below the surface of the water in the bath. It is located in the bottom of a galvanized iron can,¹ which is weighted down by a heavy iron cylinder. This also serves to distribute the heat around the bottle containing the copper sulphate solution into which the cell is placed. In addition to this precaution for securing equality of temperature between the cell and the water of the bath, the can was filled with water to a depth of about six inches. The temperature of the cell contents is taken to be that of the bath, while the air in the manometer is that of the air compartment. Thermometers with large bulbs, and carefully compared with one calibrated at the Reichsanstalt, are used in this work. The extreme variations in the temperature of the water during the entire work were between $0^{\circ}.12$ and $0^{\circ}.38$, while the more frequent variations were between $0^{\circ}.15$ and $0^{\circ}.30$. The temperature of the air space above the water, in which the tops of the manometers were located, was much more variable and always higher. The difference, however, rarely exceeded $1^{\circ}.0$, except temporarily, after the opening of the bath. The rapidly changing conditions of the temperature of the external air affected the bath to such an extent that the highest speed of the air pumps did not suffice to main-

¹ Am. Chem. J., 36, 9.

tain a constant relation between the temperatures of the water and that of the air within the bath.

*The Cell.*¹

The form of cell is the same as that used in the previous work on osmotic pressure in this laboratory. In fact the same cells have been employed in the greater part of the measurements at the low temperatures. These cells, after standing all the summer, were opened, thoroughly cleansed and refitted for a new series of measurements. The most remarkable of these cells has been designated as G. For a history of this cell, see dissertation by E. J. Hoffman, 1906. According to Hoffman the maximum membrane resistance reached when depositing the membranes, at the ordinary temperature of the room, was 375,000 ohms, while a resistance of 550,000 ohms was obtained when the deposition of the membrane was carried out at the low temperature at which these measurements were made, *i. e.*, at 0°. The depositing of the membranes at low temperatures was taken up later in a series of measurements on glucose at 0° (see dissertation by F. M. Rogers, 1907). The alternate cooling of the cells when a measurement was in progress and the warming up when the membrane was being deposited at the temperature of the room, seemed to affect the conditions of the cells and membranes to a slight extent, so it was thought necessary to deposit the membranes at the same temperature at which the measurements were taken. For this purpose simple devices in the way of small ice baths were arranged to surround each cell in the process of membrane depositing. This seemed to keep the cells in much better condition. A higher resistance of the membrane was always obtained under such circumstances.

The method of depositing the membrane of copper ferrocyanide in the cell is the same as that described by Morse and Horn in a previous paper.² A platinum cathode is placed inside of the cell and a copper anode surrounds the cell on the outside. A solution of potassium ferrocyanide in the

¹ Am. Chem. J., 28, 1; 34, 1.

² Ibid., 34, 1.

cell and one of copper sulphate on the outside are both of 0.1 normal concentration. The former was renewed every few minutes to prevent the accumulation of alkali and the consequent injury to the membrane formed.

A current pressure of about 110 volts has been found to be the most satisfactory voltage to use in the deposition of the copper ferrocyanide membrane. Before a membrane is deposited in a cell, all of the air must be removed from the cell walls by the usual method of endosmose. For this purpose both electrodes should be of platinum. A 0.005 normal solution of lithium sulphate is used as the electrolyte. After several hundred cubic centimeters of water have passed through the walls, the sulphate solution is replaced by distilled water and the electrolysis continued until all the sulphate has been removed from the cell. The cell is then filled with recently boiled distilled water and placed in a vessel of the same until it is desired to deposit the membrane.

*The Manometer.*¹

No important changes have been made in the form of manometer used in the previous work. At the lower end of the manometer, the one which enters the cell, a second enlargement was made about one-half an inch from the end. When the rubber stopper was pushed on the manometer this enlargement came about to the middle of the stopper, while the first enlargement on the extreme end, was just below the bottom of the stopper. A few turns of a fine strand of waxed shoemaker's thread was tied tightly around the lower end of the stopper before putting the manometer into the cell. The lower portions of the rubber are thus crowded downward and made to expand slightly over the small part of the upper portions of the enlargement. After the manometer has been inserted into the cell, the upper portion of the stopper, which projects beyond the glass tube in the cell, is wound very tightly with a larger strand of waxed shoemaker's thread. This binds the stopper very tightly around the second enlargement, and if these operations have been properly performed, the manometer does not ascend any further through the stopper, how-

¹ Am. Chem. J., 36, 23.

ever great the pressure in the cell may be. In this series of measurements the slipping of the manometer has been reduced to a mere trifle, and the loss in the rotation of the cell contents has been correspondingly diminished. A smaller amount of dilution is believed to have taken place than has been suspected in the previous work on osmotic pressure in this laboratory.

For a detailed description of the preparation of the manometer, the method of calibrating, filling, determination of the air volume, capillary depression, closing the manometer, etc., see the *American Chemical Journal*, 34, 6; 36, 23.

In the calibration of the manometers the average of several series of values was taken. The calibration data of one of these manometers will be given here.

For convenience of use the above data were reduced to a calibration unit and plotted in the form of a curve. Other data which have been used in the computation of pressures with this manometer are as follows:

Distance between scratches = 319.54 mm.

Distance from bottom scratch to top of manometer = 466.53 mm.

Weight of mercury thread used in its calibration = 0.0678 gram.

Average diameter of bore of manometer tube = 0.69 mm.

Correction for meniscus = 0.23 calibration unit.

Number of calibration units of air in manometer = 471.37.

Number of calibration units in mercury thread used in calibrating the manometer = 13.413.

This latter was the average length of the thread taken in the 35 times it was set end to end throughout the calibration of the instrument. This value was verified by afterwards introducing into the tube a long thread which very nearly filled the calibrated portion, its length being 438.60 mm. at 20°.5 and weighing, when corrected for air displacement, 2.2505 grams. The bore of the tube was again calculated from this and gave a mean diameter of 0.6945 mm. Before the manometers were filled and closed, their capillary depression was determined. It next becomes necessary to deter-

Table A.—*Calibration Data of Manometer No. 21.*

No. of readings.	Readings upwards on scale.	Lengths of thread.	Distance from scratch as zero.	Product of No. of readings by mean length of thread.	Correction values.
0	796.77				
1	783.18	13.59	13.59	13.413	—0.177
2	769.60	13.58	27.17	26.826	—0.344
3	756.02	13.58	40.75	40.239	—0.511
4	742.45	13.57	54.32	53.652	—0.668
5	728.89	13.56	67.88	67.065	—0.825
6	715.34	13.55	81.43	80.478	—0.952
7	701.80	13.54	94.97	93.891	—1.079
8	688.28	13.52	108.49	107.304	—1.186
9	674.77	13.51	122.00	120.717	—1.283
10	661.27	13.50	135.50	134.130	—1.370
11	647.77	13.50	149.00	147.543	—1.457
12	634.28	13.49	162.49	160.956	—1.534
13	620.79	13.49	175.98	174.369	—1.611
14	607.30	13.49	189.47	187.782	—1.688
15	593.82	13.48	202.95	201.195	—1.755
16	580.35	13.47	216.42	214.608	—1.812
17	566.90	13.45	229.87	228.021	—1.849
18	553.46	13.44	243.31	241.434	—1.876
19	540.03	13.43	256.74	254.847	—1.893
20	526.62	13.41	270.15	268.260	—1.890
21	513.21	13.41	283.56	281.673	—1.887
22	499.81	13.40	296.96	295.086	—1.874
23	486.42	13.39	310.35	308.499	—1.851
24	473.04	13.38	323.73	321.912	—1.818
25	459.68	13.36	337.09	335.325	—1.765
26	446.34	13.34	350.43	348.738	—1.692
27	433.02	13.32	363.75	362.151	—1.599
28	419.72	13.30	377.05	375.564	—1.486
29	406.44	13.28	390.33	388.977	—1.353
30	393.18	13.26	403.59	402.390	—1.200
31	379.95	13.23	416.82	415.803	—1.017
32	366.75	13.20	430.02	429.216	—0.814
33	353.58	13.17	443.19	442.629	—0.561
34	340.44	13.14	456.33	456.042	—0.288
35	327.33	13.11	469.44	469.455	+0.015

mine the total air volume of the manometer after it has been filled. This has been accomplished by means of a glass tube bent at two right angles, the manometer being attached to one ascending limb and a piece of tubing, the same bore as the manometer, to the other. The horizontal portion has a reservoir tube sealed on to it, into which a screw plunger is inserted in order to adjust the height of the mercury in the manometer and side tube. This device takes the place of the rubber tube formerly used. Great difficulty was experienced in securing satisfactory results with the rubber connection used between the manometer and reservoir tube. The experiments carried out with the glass tube gave much more concordant results and the air volume can be determined in a much shorter time. The whole apparatus is placed before the cathetometer, and after uniform temperature has been secured, readings are made on the height of the mercury in the manometer and in the side tube, the top of the manometer and the bottom scratch. The barometer is read and temperature of the room taken. Several sets of readings are taken in this manner and from them may be determined the air volume contained in the manometer under standard conditions, 0° and 760 mm. pressure.

EXPERIMENTAL PART.

The material employed for the measurements was the purest obtainable "rock candy." It left no ash when burned and gave no reaction for invert sugar with Fehling's solution. The usual determination of carbon and hydrogen was omitted, but not that with the polariscope. This is a more sensitive test than the combustion method. The standard solution¹ was made up, containing 26.0039 grams of sugar in 100 cc. of solution at $17^{\circ}.5$, giving a rotation of 99.95, instead of 100, saccharimeter degrees.

The details of the individual measurements are presented in the following tables:

¹ Landolt, *Das Optische Drehungsvermögen*, U. S. W., p. 335.

Table I.

Original wt. normal concentration of solution, 0.1. Experiment No. I
 Rotation of original solution, $12^{\circ}.5$ ($t = 22^{\circ}$). Manometer used, No. 18.
 Rotation at conclusion of exp't, $12^{\circ}.3$ ($t = 22^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $0^{\circ}.2 = 1.60$ per cent. Cell used, B.
 Calibration units of air in manometer, 476.96. Resistance of membrane, 137,500 ohms.
 Time of setting up cell, 12.00 noon, Dec. 14, 1906. Initial pressure, 1.74 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 14.									
1.10 P.M.	$0^{\circ}.22$	$4^{\circ}.1$							
4.20 "	$0^{\circ}.18$	$0^{\circ}.55$							
"	$0^{\circ}.20$	$0^{\circ}.52$	159.50	159.20	1.01	0.43	0.03	0.02	+0.18
8.00 "	$0^{\circ}.18$	$0^{\circ}.56$	159.39	159.06	1.01	0.43	0.03	0.02	+0.18
Dec. 15.									
10.45 A.M.	$0^{\circ}.28$	$0^{\circ}.65$	159.37	158.99	1.00	0.43	0.03	0.02	+0.19
12.30 P.M.	$0^{\circ}.30$	$0^{\circ}.84$	159.40	158.90	1.00	0.43	0.03	0.02	+0.19
4.00 "	$0^{\circ}.36$	$0^{\circ}.91$	159.42	158.92	1.00	0.43	0.03	0.02	+0.19

Displacement of the manometer = 0.07 mm.

Table II.

Original wt. normal concentration of solution, 0.1.									
Rotation of original solution, $12^{\circ}.5$ ($t = 20^{\circ}$).									
Rotation at conclusion of exp't, $12^{\circ}.4$ ($t = 20^{\circ}$).									
Loss in rotation, $0^{\circ}.1 = 0.80$ per cent.									
Calibration units of air in manometer, 476.96.									
Time of setting up cell, 3.30 P. M., Dec. 17, 1906.									
Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 17.									
5.00 P.M.	$0^{\circ}.23$	$3^{\circ}.00$							
7.30 "	$0^{\circ}.22$	$0^{\circ}.80$							
11.45 "	$0^{\circ}.14$	$0^{\circ}.69$	159.48	159.08	1.00	0.43	0.01	0.02	+0.21
Dec. 18.									
10.00 A.M.	$0^{\circ}.26$	$0^{\circ}.59$	158.71	158.37	1.01	0.43	0.01	0.02	+0.21
12.45 P.M.	$0^{\circ}.22$	$0^{\circ}.56$	158.66	158.33	1.01	0.43	0.01	0.02	+0.21
4.00 "	$0^{\circ}.22$	$0^{\circ}.56$	158.59	158.26	1.01	0.43	0.01	0.02	+0.21

Displacement of the manometer = 0.07 mm.

Table III.

Original wt. normal concentration of solution, 0.1.
 Rotation of original solution, $12^{\circ}.65$ ($t = 18^{\circ}.5$).
 Rotation at conclusion of exp't, $12^{\circ}.60$ ($t = 18^{\circ}.5$).
 Loss in rotation, $0^{\circ}.05 = 0.39$ per cent.
 Calibration units of air in manometer, 434.93.
 Time of setting up cell, 3.30 P. M., Jan. 11, 1907.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	
Jan. 11.									
4.45 P.M.	$0^{\circ}.24$	$3^{\circ}.00$	205.93	205.12					
11.30 "	$0^{\circ}.14$	$0^{\circ}.89$	152.39	151.88	1.00	0.48	0.01	0.02	+0.13
Jan. 12.									
10.30 A.M.	$0^{\circ}.14$	$0^{\circ}.95$	152.08	151.55					
1.00 P.M.	$0^{\circ}.24$	$1^{\circ}.12$	152.15	151.52	1.00	0.48	0.01	0.02	+0.13
4.30 "	$0^{\circ}.24$	$1^{\circ}.20$	152.10	151.44	0.99	0.48	0.01	0.02	+0.14
7.30 "	$0^{\circ}.28$	$1^{\circ}.30$	152.11	151.39	0.99	0.48	0.01	0.02	+0.14
Jan. 13.									
10.15 "	$0^{\circ}.38$	$1^{\circ}.17$	151.11	150.46	1.00	0.48	0.01	0.02	+0.13

Displacement of the manometer = 0.09 mm.

Table IV.

Original wt. normal concentration of solution, 0.1.					Experiment No. 4.					Difference between pressure found and calculated.	
Rotation of original solution, 12°.65 (<i>t</i> = 18°.5).					Manometer used, No. 6.						
Rotation at conclusion of exp't, 12°.55 (<i>t</i> = 18°.5).					Capillary depression, 0.02.						
Loss in rotation, 0°.1 = 0.79 per cent.					Cell used, A.						
Calibration units of air in manometer, 396.89.					Resistance of membrane, 157,000 ohms.						
Time of setting up cell, 4.00 P. M., Jan. 11, 1907.					Initial pressure, 1.34 atmospheres.						
					Corrections.						
		Temperature.		Volume of air in manometer.		Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.
Time.		Air in manometer.		Uncorrected. Corrected.							
Jan. 11.											
4.45 P.M.		0°.24	3°.00	219.57							
11.30 "		0°.14	0°.89	160.90	160.38						
Jan. 12.											
10.30 A.M.		0°.14	0°.95	139.62	139.14	1.00	0.49	0.01	0.02	2.37	2.23
1.00 P.M.		0°.24	1°.12	139.58	139.02	0.99	0.49	0.01	0.02	2.38	2.23
4.30 "		0°.24	1°.20	139.43	138.82	0.99	0.49	0.01	0.02	2.39	2.23
7.30 "		0°.28	1°.30	139.31	138.65	1.00	0.49	0.01	0.02	2.38	2.23
Jan. 13.											
10.15 A.M.		0°.38	1°.17	138.58	137.99	1.01	0.49	0.01	0.02	2.39	2.23
Displacement of the manometer = 0.09 mm.											

Displacement of the manometer = 0.09 mm.

Original wt. normal concentration of solution, 0.1. Experiment No. 4.
 Rotation of original solution, 12°.65 ($t = 18^\circ.5$). Manometer used, No. 6.
 Rotation at conclusion of exp't, 12°.55 ($t = 18^\circ.5$). Capillary depression, 0.02.
 Loss in rotation, 0°.1 = 0.79 per cent. Cell used, A.
 Calibration units of air in manometer, 396.89. Resistance of membrane, 157,000 ohms.
 Time of setting up cell, 4.00 P. M., Jan. 11, 1907. Initial pressure, 1.34 atmospheres.

Table V.

Original wt. normal concentration of solution, 0.2.
 Rotation of original solution, $24^{\circ}.75$ ($t = 21^{\circ}$).
 Rotation at conclusion of exp't, $24^{\circ}.60$ ($t = 21^{\circ}$).
 Loss in rotation, $0^{\circ}.15 = 0.61$ per cent.
 Calibration units of air in manometer, 476.96.
 Time of setting up cell, 4.00 P. M., Dec. 19, 1906.
 Experiment No. 1.
 Manometer used, No. 18.
 Capillary depression, 0.02.
 Cell used, B.
 Resistance of membrane, 124,000 ohms.
 Initial pressure, 4.09 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.				Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 19.									
5.30 P.M.	$0^{\circ}.13$	$2^{\circ}.30$							
7.30 "	$0^{\circ}.14$	$0^{\circ}.87$							
11.00 "	$0^{\circ}.16$	$0^{\circ}.69$	91.35	91.12	1.01	0.52	0.02	0.02	+0.28
Dec. 20.									
10.00 A.M.	$0^{\circ}.20$	$0^{\circ}.77$	91.27	91.01	1.00	0.52	0.02	0.02	+0.30
12.45 P.M.	$0^{\circ}.24$	$0^{\circ}.88$	91.35	91.06	0.99	0.52	0.02	0.02	+0.31
3.30 "	$0^{\circ}.26$	$0^{\circ}.91$	91.32	91.02	0.99	0.52	0.02	0.02	+0.31

Displacement of the manometer = 0.05 mm.

Table VI.

Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 21.									
5.30 P.M.	0°.26	2°.40							
7.30 "	0°.28	1°.05							
10.00 "	0°.28	0°.99	91.90	91.57	0.99	0.52	0.02	0.02	+0.28
Dec. 22.									
9.30 A.M.	0°.28	0°.82	91.57	91.30	0.99	0.52	0.02	0.02	+0.29
1.00 P.M.	0°.32	0°.85	91.48	91.20	0.99	0.52	0.02	0.02	+0.30
5.00 "	0°.31	0°.95	91.49	91.17	0.99	0.52	0.02	0.02	+0.30

Displacement of the manometer = 0.05 mm.

Original wt. normal concentration of solution, 0.2.
 Rotation of original solution, 24°.8 ($t = 21^\circ$).
 Rotation at conclusion of exp't, 24°.65 ($t = 21^\circ$).
 Loss in rotation, 0°.15 = 0.60 per cent.
 Calibration units of air in manometer, 476.96.
 Time of setting up cell, 4.00 P. M., Dec. 21, 1906.

Experiment No. 2.
 Manometer used, No. 18.
 Capillary depression, 0.02.
 Cell used, B.
 Resistance of membrane, 122,000 ohms.
 Initial pressure, 3.79 atmospheres.

Table VII.

Original wt. normal concentration of solution, 0.3. Experiment No. 1.
 Rotation of original solution, $36^{\circ}.6$ ($t = 22^{\circ}$). Manometer used, No. 21.
 Rotation at conclusion of exp't, $36^{\circ}.1$ ($t = 22^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $0^{\circ}.5 = 1.37$ per cent. Cell used, B.
 Calibration units of air in manometer, 471.37. Resistance of membrane, 158,000 ohms.
 Time of setting up cell, 4.00 P. M., Dec. 5, 1906. Initial pressure, 5.01 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	
Dec. 5.								
5.30 P.M.	$0^{\circ}.16$	$1^{\circ}.93$						
9.30 "	$0^{\circ}.14$	$0^{\circ}.59$						
Dec. 6.								
10.00 A.M.	$0^{\circ}.18$	$0^{\circ}.70$	63.30	63.14	0.99	0.58	0.07	6.68
12.30 P.M.	$0^{\circ}.22$	$0^{\circ}.89$	63.27	63.07	0.98	0.58	0.07	6.68
5.00 "	$0^{\circ}.30$	$1^{\circ}.08$	63.31	63.06	0.98	0.58	0.07	6.69
10.30 "	$0^{\circ}.33$	$1^{\circ}.00$	63.33	63.10	0.99	0.58	0.07	6.69
Dec. 7.								
10.00 A.M.	$0^{\circ}.34$	$0^{\circ}.70$	63.12	62.96	1.00	0.58	0.07	6.69
12.50 P.M.	$0^{\circ}.33$	$0^{\circ}.74$	63.14	62.97	1.00	0.58	0.07	6.69
4.10 "	$0^{\circ}.34$	$0^{\circ}.64$	63.15	63.00	1.00	0.58	0.07	6.69

Displacement of the manometer = 0.06 mm.

Table VIII.

Original wt. normal concentration of solution, 0.3.									
Rotation of original solution, $36^{\circ}.6$ ($t = 20^{\circ}$).									
Rotation at conclusion of exp't, $36^{\circ}.0$ ($t = 20^{\circ}$).									
Loss in rotation, $0^{\circ}.6 = 1.64$ per cent.									
Calibration units of air in manometer, 476.96.									
Time of setting up cell, 4.00 P. M., Dec. 11, 1906.									
Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 11.									
5.30 P.M.	$0^{\circ}.16$	$1^{\circ}.54$							
9.15 "	$0^{\circ}.16$	$0^{\circ}.44$							
Dec. 12.									
12.10 A.M.	$0^{\circ}.15$	$0^{\circ}.36$	63.43	63.34	1.01	0.56	0.08	0.02	+0.34
10.00 "	$0^{\circ}.14$	$0^{\circ}.29$	63.35	63.28	1.02	0.56	0.08	0.02	+0.34
12.50 P.M.	$0^{\circ}.14$	$0^{\circ}.37$	63.35	63.27	1.01	0.56	0.08	0.02	+0.35
3.50 "	$0^{\circ}.18$	$0^{\circ}.53$	63.36	63.24	1.01	0.56	0.08	0.02	+0.35

Displacement of the manometer = 0.06 mm.

Table IX.

Original wt. normal concentration of solution, 0.4.
 Rotation of original solution, $47^{\circ}.85$ ($t = 22^{\circ}$).
 Rotation at conclusion of exp't, $47^{\circ}.30$ ($t = 22$).
 Loss in rotation, $0^{\circ}.55 = 1.15$ per cent.
 Calibration units of air in manometer, 434.93.
 Time of setting up cell, 4.00 P. M., Dec. 26, 1906.

Experiment No. 1.
 Manometer used, No. 13.
 Capillary depression, 0.02.
 Cell used, B.

Resistance of membrane, 140,000 ohms.
 Initial pressure, 7.73 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.				Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	
Dec. 26.									
5.00 P.M.	$0^{\circ}.18$	$3^{\circ}.30$	54.32						
8.00 "	$0^{\circ}.16$	$0^{\circ}.75$	45.32						
11.00 "	$0^{\circ}.16$	$0^{\circ}.63$	44.88	44.78	1.00	0.62	0.08	0.02	8.91 + 0.36
Dec. 27.									
9.45 A.M.	$0^{\circ}.16$	$0^{\circ}.57$	44.78	44.69	1.00	0.62	0.08	0.02	8.91 + 0.38
12.30 P.M.	$0^{\circ}.20$	$0^{\circ}.71$	44.80	44.69	1.00	0.62	0.08	0.02	8.91 + 0.38
4.00 "	$0^{\circ}.22$	$0^{\circ}.79$	44.79	44.66	0.99	0.62	0.08	0.02	8.91 + 0.40

Displacement of the manometer = 0.08 mm.

Table X.

Original wt. normal concentration of solution, 0.4. Experiment No. 2.
 Rotation of original solution, $48^{\circ}.0$ ($t = 20^{\circ}$). Manometer used, No. 6.
 Rotation at conclusion of exp't, $47^{\circ}.4$ ($t = 20^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $0^{\circ}.6$ (1.25 per cent). Cell used, B.
 Calibration units of air in manometer, 396.89. Resistance of membrane, 124,444 ohms.
 Time of setting up cell, 4.00 P. M., Dec. 28, 1906. Initial pressure, 6.60 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	
Dec. 28.								
5.00 P.M.	$0^{\circ}.22$	$3^{\circ}.5$	57.85					
7.30 "	$0^{\circ}.23$	$1^{\circ}.07$						
11.15 "	$0^{\circ}.22$	$1^{\circ}.04$	41.24	41.08	1.00	0.65	0.08	+0.34
Dec. 29.								
9.15 A.M.	$0^{\circ}.26$	$1^{\circ}.03$	41.24	41.08	1.00	0.65	0.08	+0.33
1.00 P.M.	$0^{\circ}.33$	$1^{\circ}.17$	41.22	41.04	1.00	0.65	0.08	+0.34
4.00 "	$0^{\circ}.32$	$1^{\circ}.26$	41.23	41.04	1.00	0.65	0.08	+0.34

Displacement of the manometer = 0.07 mm.

Table XI.

Original wt. normal concentration of solution, 0.4.
 Rotation of original solution, $48^{\circ}.0$ ($t = 20^{\circ}$).
 Rotation at conclusion of exp't, $47^{\circ}.6$ ($t = 20^{\circ}$).
 Loss in rotation, $0^{\circ}.4 = 0.83$ per cent.
 Calibration units of air in manometer, 434.98.
 Time of setting up cell, 3.30 P. M., Jan. 5, 1907.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Capillary depression.	
Jan. 5.								
5.15 P.M.	$0^{\circ}.26$	$3^{\circ}.00$	55.49					
8.00 "	$0^{\circ}.18$	$1^{\circ}.18$	45.56					
12.00 "	$0^{\circ}.20$	$0^{\circ}.97$	45.23					
Jan. 6.								
10.00 A.M.	$0^{\circ}.22$	$0^{\circ}.85$	45.21					
2.45 P.M.	$0^{\circ}.24$	$0^{\circ}.96$	45.21					
7.30 "	$0^{\circ}.26$	$1^{\circ}.01$	45.04	44.87	1.00	0.63	0.06	+0.36
Jan. 7.								
10.15 A.M.	$0^{\circ}.32$	$1^{\circ}.17$	45.00	44.81	1.01	0.63	0.06	+0.37
12.30 P.M.	$0^{\circ}.34$	$1^{\circ}.39$	44.99	44.76	1.00	0.63	0.06	+0.39
3.45 "	$0^{\circ}.34$	$1^{\circ}.54$	45.01	44.75	1.00	0.63	0.06	+0.39

Displacement of the manometer = 0.22 mm.

Table XII.

Experiment No. 4.										
Manometer used, No. 6.										
Capillary depression, 0.02.										
Cell used, D.										
Resistance of membrane, 93,000 ohms.										
Initial pressure, 8.08 atmospheres.										

Displacement of the manometer = 0.04 mm.

Table XIII.

Original wt. normal concentration of solution, 0.5.
 Rotation of original solution, $58^{\circ}.7$ ($t = 19^{\circ}.5$).
 Rotation at conclusion of exp't, $57^{\circ}.8$ ($t = 19^{\circ}.5$).
 Loss in rotation, $0^{\circ}.9 = 1.53$ per cent.
 Calibration units of air in manometer, 471.37.
 Time of setting up cell, 5.00 P. M., Nov. 26, 1906.
 Experiment No. 1.
 Manometer used, No. 21.
 Capillary depression, 0.02.
 Cell used, G.
 Resistance of membrane, 58,947 ohms.
 Initial pressure, 11.03 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	
Nov. 26.								
7.30 P.M.	$0^{\circ}.24$	$1^{\circ}.88$						
11.10 "	$0^{\circ}.26$	$1^{\circ}.69$						
Nov. 27.								
10.10 A.M.	$0^{\circ}.33$	$1^{\circ}.80$	39.46	39.20	1.00	0.61	0.13	+0.39
12.40 P.M.	$0^{\circ}.38$	$1^{\circ}.99$	39.50	39.21	1.00	0.61	0.13	+0.37
3.30 "	$0^{\circ}.38$	$2^{\circ}.03$	39.48	39.19	1.00	0.61	0.13	+0.38
7.30 "	$0^{\circ}.16$	$1^{\circ}.29$	39.36	39.18	1.01	0.61	0.13	+0.38
11.15 "	$0^{\circ}.14$	$1^{\circ}.20$	39.28	39.11	1.00	0.61	0.13	+0.42
Nov. 28.								
10.00 A.M.	$0^{\circ}.18$	$1^{\circ}.33$	39.36	39.17	1.00	0.61	0.13	+0.40

Displacement of the manometer = 0.24 mm.

Table XIV.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.		
Nov. 30.										
3.30 P.M.	0°.22	0°.77								
7.30 "	0°.20	0°.69								
11.00 "	0°.20	0°.69	39.19	39.09	1.00	0.61	0.14	0.02	11.55	+0.41
Dec. 1.										
9.15 A. M.	0°.26	0°.76	39.05	38.94	1.00	0.61	0.14	0.02	11.60	+0.46
12.40 P.M.	0°.22	0°.81	39.03	38.91	1.00	0.61	0.14	0.02	11.61	+0.47
4.00 "	0°.22	0°.79	39.04	38.93	1.00	0.61	0.14	0.02	11.60	+0.46

Displacement of the manometer = 0.22.

Original wt. normal concentration of solution, 0.5.
 Experiment No. 2.
 Rotation of original solution, 58°.75 ($t = 18^{\circ}.5$).
 Manometer used, No. 21.
 Rotation at conclusion of exp't, 57°.75 ($t = 18^{\circ}.5$).
 Capillary depression, 0.02.
 Loss in rotation, 1°.00 = 1.70 per cent.
 Cell used, G.
 Calibration units of air in manometer, 471.37.
 Resistance of membrane, 135,000 ohms.
 Time of setting up cell, 12.30 P. M., Nov. 30, 1906. Initial pressure, 11.39 atmospheres.

Table XV.

Original wt. normal concentration of solution, 0.5. Experiment No. 3.
 Rotation of original solution, $58^{\circ}.80$ ($t = 20^{\circ}$). Manometer used, No. 18.
 Rotation at conclusion of exp't, $57^{\circ}.75$ ($t = 20^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $1^{\circ}.05 = 1.71$ per cent. Cell used, G.
 Calibration units of air in manometer, 476.96. Resistance of membrane, 110,000 ohms.
 Time of setting up cell, 3.30 P. M., Dec. 3, 1906. Initial pressure, 11.30 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Capillary depression.		
Dec. 3									
5.20 P.M.	$0^{\circ}.16$	$5^{\circ}.00$							
7.45 "	$0^{\circ}.16$	$0^{\circ}.66$							
11.15 "	$0^{\circ}.14$	$0^{\circ}.39$							
Dec. 4									
10.20 A.M.	$0^{\circ}.12$	$0^{\circ}.20$	39.10	39.07	1.01	0.59	0.15	11.65	+0.51
12.45 P.M.	$0^{\circ}.12$	$0^{\circ}.25$	39.13	39.09	1.01	0.59	0.15	11.65	+0.51
3.45 "	$0^{\circ}.12$	$0^{\circ}.33$	39.17	39.12	1.01	0.59	0.15	11.64	+0.50
7.45 "	$0^{\circ}.14$	$0^{\circ}.39$	39.17	39.11	1.00	0.59	0.15	11.65	+0.51
11.00 "	$0^{\circ}.15$	$0^{\circ}.40$	39.16	39.10	1.01	0.59	0.15	11.64	+0.50
Dec. 5									
10.10 A.M.	$0^{\circ}.18$	$0^{\circ}.38$	39.15	39.09	1.01	0.59	0.15	11.65	+0.51
4.15 P.M.	$0^{\circ}.18$	$0^{\circ}.52$	39.18	39.11	1.00	0.59	0.15	11.65	+0.51

Displacement of the manometer = 0.07.

Table XVI.

Original wt. normal concentration of solution, 0.5.
 Rotation of original solution, $58^{\circ}.85$ ($t = 20^{\circ}$).
 Rotation at conclusion of exp't, $58^{\circ}.10$ ($t = 20^{\circ}$).
 Loss in rotation, $0^{\circ}.75 = 1.29$ per cent.
 Calibration units of air in manometer, 465.78.
 Time of setting up cell, 4.30 P. M., Jan. 4, 1907.

Experiment No. 4.
 Manometer used, No. 11.
 Capillary depression, 0.02.
 Cell used, D.
 Resistance of membrane, 90,000 ohms.
 Initial pressure, 8.13 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.			
Jan. 4										
5.15 P.M.	$0^{\circ}.26$	$2^{\circ}.10$	54.70							
8.00 "	$0^{\circ}.16$	$1^{\circ}.07$	38.70							
10.45 "	$0^{\circ}.16$	$0^{\circ}.97$	38.31	38.17	1.00	0.56	0.11	11.67	11.14	+0.53
Jan. 5										
10.30 A.M.	$0^{\circ}.18$	$0^{\circ}.89$	38.24	38.12	1.01	0.56	0.11	11.68	11.14	+0.54
1.00 P.M.	$0^{\circ}.20$	$1^{\circ}.09$	38.28	38.13	1.00	0.56	0.11	11.69	11.14	+0.55
4.00 "	$0^{\circ}.26$	$1^{\circ}.26$	38.31	38.12	1.00	0.56	0.11	11.69	11.14	+0.55

Displacement of the manometer = 0.38 mm.

Table XVII.

Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.			
Dec. 31.											
6.00 P.M.	0° 22	2° 00	35.26								
11.00 "	0° 16	1° 34	30.19	30.04	1.00	0.64	0.12	0.02	14.02	13.37	+0.65
Jan. 1, '07											
10.00 A.M.	0° 22	1° 20	30.19	30.06	1.00	0.64	0.12	0.02	14.01	13.37	+0.64
12.30 P.M.	0° 22	1° 29	30.19	30.05	1.00	0.64	0.12	0.02	14.01	13.37	+0.64
5.30 "	0° 24	1° 28	30.21	30.07	1.01	0.64	0.12	0.02	13.99	13.37	+0.62
7.30 "	0° 28	1° 43	30.24	30.08	1.01	0.64	0.12	0.02	13.99	13.37	+0.62
11.00 "	0° 25	1° 36	30.24	30.09	1.01	0.64	0.12	0.02	13.98	13.37	+0.61
Jan. 2, '07											
9.30 A.M.	0° 24	1° 10	30.18	30.06	1.01	0.64	0.12	0.02	14.00	13.37	+0.63

Displacement of the manometer = 0.48 mm.

Original wt. normal concentration of solution, 0.6. Experiment No. I.
 Rotation of original solution, 69° 4 ($t = 19^\circ$). Manometer used, No. 13.
 Rotation at conclusion of exp't, 68° 2 ($t = 19^\circ$). Capillary depression, 0.02.
 Loss in rotation, 1° 2 = 1.73 per cent. Cell used, B.
 Calibration units of air in manometer, 434.93. Resistance of membrane, 161,000 ohms.
 Time of setting up cell, 4.30 P. M., Dec. 31, 1906. Initial pressure, 12.08 atmospheres.

Table XVIII.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.			
Jan. 2.										
5.00 P.M.	0°.24	3°.3	29.97	27.53	1.01	0.67	0.14	13.96	13.37	+0.59
8.00 "	0°.20	1°.01	27.63	27.51	1.01	0.67	0.14	13.97	13.37	+0.60
10.30 "	0°.20	0°.94	27.60	27.49	1.01	0.67	0.14	13.98	13.37	+0.61
Jan. 3.										
10.15 A.M.	0°.20	0°.84	27.63	27.55	1.01	0.67	0.14	13.95	13.37	+0.58
1.00 P.M.	0°.22	0°.92	27.60	27.51	1.01	0.67	0.14	13.97	13.37	+0.60
4.15 "	0°.25	0°.95	27.59	27.49	1.01	0.67	0.14	13.98	13.37	+0.61

Displacement of the manometer = 0.10 mm.

Original wt. normal concentration of solution, 0.6. Experiment No. 2.
 Rotation of original solution, 69°.35 ($t = 20^\circ$). Manometer used, No. 6.
 Rotation at conclusion of exp't, 68°.05 ($t = 20^\circ$). Capillary depression, 0.02.
 Loss in rotation, 1°.30 = 1.86 per cent. Cell used, G.
 Calibration units of air in manometer, 369.89. Resistance of membrane, 102,000 ohms.
 Time of setting up cell, 4.00 P. M., Jan. 2, 1907. Initial pressure, 13.09 atmospheres.

Table XIX.

Original wt. normal concentration of solution, 0.7. Experiment No. 1.
 Rotation of original solution, $79^{\circ}.3$ ($t = 20^{\circ}$). Manometer used, No. 13.
 Rotation at conclusion of exp't, $78^{\circ}.1$ ($t = 20^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $1^{\circ}.2 = 1.51$ per cent. Cell used, B.
 Calibration units of air in manometer, 434.93. Resistance of membrane, 159,300 ohms.
 Time of setting up cell, 4.00 P.M., Jan. 3, 1907. Initial pressure, 13.53 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	
Jan. 3.								
5.15 P.M.	$0^{\circ}.18$	$2^{\circ}.80$	31.68					
8.15 "	$0^{\circ}.16$	$0^{\circ}.91$	25.85					
10.45 "	$0^{\circ}.16$	$0^{\circ}.93$	25.74	25.65	1.00	0.65	0.18	+0.85
Jan. 4.								
10.00 A.M.	$0^{\circ}.26$	$1^{\circ}.29$	25.73	25.61	0.99	0.65	0.18	+0.88
12.45 P.M.	$0^{\circ}.30$	$1^{\circ}.38$	25.75	25.62	0.99	0.65	0.18	+0.88
4.15 "	$0^{\circ}.32$	$1^{\circ}.19$	25.74	25.64	1.00	0.65	0.18	+0.86

Displacement of the manometer = 0.61 mm.

Table XX.

Original wt. normal concentration of solution, 0.7.										
Rotation of original solution, $79^{\circ}.3$ ($t = 20^{\circ}$).										
Rotation at conclusion of exp't, $78^{\circ}.2$ ($t = 20^{\circ}$).										
Loss in rotation, $1^{\circ}.1 = 1.39$ per cent.										
Calibration units of air in manometer, 396.89.										
Time of setting up cell, 1.30 P. M., Jan. 18, 1907.										
Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.		Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.			
Jan. 18										
1.15 P.M.	$0^{\circ}.16$	$4^{\circ}.5$	28.51							
5.15 "	$0^{\circ}.14$	$0^{\circ}.59$	23.37	23.32	1.00	0.67	0.16	16.55	15.60	+0.95
7.30 "	$0^{\circ}.16$	$0^{\circ}.83$	23.40	23.33	1.00	0.67	0.16	16.54	15.60	+0.94
11.45 "	$0^{\circ}.14$	$0^{\circ}.76$	23.37	23.31	1.00	0.67	0.16	16.56	15.60	+0.96
Jan. 19										
10.30 A.M.	$0^{\circ}.16$	$0^{\circ}.71$	23.41	23.35	1.00	0.67	0.16	16.53	15.60	+0.93

Displacement of the manometer = 0.45 mm.

Displacement of the manometer = 0.45 mm.

Table XXI.

Original wt. normal concentration of solution, 0.8. Experiment No. 1.
 Rotation of original solution, $89^{\circ}.15$ ($t = 20^{\circ}$). Manometer used, No. 6.
 Rotation at conclusion of exp't, $87^{\circ}.60$ ($t = 20^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $1^{\circ}.55 = 1.74$ per cent. Cell used, G.
 Calibration units of air in manometer, 396.89. Resistance of membrane, 112,000 ohms.
 Time of setting up cell, 4.00 P. M., Jan. 4, 1907. Initial pressure, 17.64 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	
Jan. 4								
5.15 P.M.	$0^{\circ}.26$	$2^{\circ}.10$	22.28					
8.00 "	$0^{\circ}.16$	$1^{\circ}.07$	20.54					
10.45 "	$0^{\circ}.16$	$0^{\circ}.97$	20.43	20.36	1.00	0.68	0.23	17.82
Jan. 5								+1.14
10.30 A.M.	$0^{\circ}.18$	$0^{\circ}.89$	20.46	20.39	1.01	0.68	0.23	17.82
1.00 P.M.	$0^{\circ}.20$	$1^{\circ}.09$	20.49	20.41	1.00	0.68	0.23	17.82
4.00 "	$0^{\circ}.26$	$1^{\circ}.26$	20.50	20.41	1.00	0.68	0.23	17.83

Displacement of the manometer = 0.01 mm.

Table XXII.

Original wt. normal concentration of solution, 0.8. Experiment No. 2.
 Rotation of original solution, $89^{\circ}.0$ ($t = 20^{\circ}.5$). Manometer used, No. 6.
 Rotation at conclusion of exp't, $87^{\circ}.4$ ($t = 20^{\circ}.5$). Capillary depression, 0.02.
 Loss in rotation, $1^{\circ}.6 = 1.80$ per cent. Cell used, G.
 Calibration units of air in manometer, 396.89. Resistance of membrane, 110,000 ohms.
 Time of setting up cell, 4.15 P. M., Jan. 14, 1907. Initial pressure, 17.68 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.		Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.			
Jan. 14.										
6.00 P.M.	$0^{\circ}.22$	$2^{\circ}.60$	22.27							
7.30 "	$0^{\circ}.16$	$1^{\circ}.19$	20.60	20.51	1.00	0.67				
11.00 "	$0^{\circ}.16$	$1^{\circ}.00$	20.47	20.40	1.00	0.67	0.24	0.02	17.82	+ 1.09
Jan. 15										
10.15 A.M.	$0^{\circ}.22$	$0^{\circ}.96$	20.49	20.42	1.00	0.67	0.24	0.02	17.82	+ 1.07
1.00 P.M.	$0^{\circ}.26$	$1^{\circ}.06$	20.48	20.40	1.00	0.67	0.24	0.02	17.83	+ 1.08
5.00 "	$0^{\circ}.26$	$1^{\circ}.06$	20.48	20.40	1.00	0.67	0.24	0.02	17.83	+ 1.08
8.00 "	$0^{\circ}.26$	$0^{\circ}.96$	20.49	20.42	1.01	0.67	0.24	0.02	17.83	+ 1.05
11.30 "	$0^{\circ}.26$	$0^{\circ}.91$	20.46	20.39	1.01	0.67	0.24	0.02	17.83	+ 1.07
Jan. 16										
10.15 A.M.	$0^{\circ}.26$	$0^{\circ}.69$	20.47	20.42	1.01	0.67	0.24	0.02	17.83	+ 1.05
1.00 P.M.	$0^{\circ}.26$	$0^{\circ}.80$	20.48	20.42	1.01	0.67	0.24	0.02	17.83	+ 1.05
3.30 "	$0^{\circ}.26$	$0^{\circ}.80$	20.47	20.41	1.01	0.67	0.24	0.02	17.83	+ 1.06

Displacement of the manometer = 0.34 mm.

Table XXIII.

Original wt. normal concentration of solution, 0.9.
 Rotation of original solution, $98^{\circ}.30$ ($t = 21^{\circ}$).
 Rotation at conclusion of exp't, $96^{\circ}.45$ ($t = 21^{\circ}$).
 Loss in rotation, $1^{\circ}.85 = 1.88$ per cent.
 Calibration units of air in manometer, 434.93.
 Time of setting up cell, 3.30 P. M., Dec. 20, 1906.
 Experiment No. 1.
 Manometer used, No. 13.
 Capillary depression, 0.02.
 Cell used, G.
 Resistance of membrane, 101,000 ohms.
 Initial pressure, 20.05 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Capillary depression.		
Dec. 20									
4.45 P.M.	$0^{\circ}.22$	$2^{\circ}.50$							
7.30 "	$0^{\circ}.26$	$0^{\circ}.94$							
Dec. 21									
12.30 A.M.	$0^{\circ}.31$	$0^{\circ}.83$	19.63	19.57	0.99	0.66	0.29	21.62	+1.56
10.00 "	$0^{\circ}.30$	$0^{\circ}.84$	19.62	19.56	0.99	0.66	0.29	21.64	+1.58
12.30 P.M.	$0^{\circ}.32$	$0^{\circ}.99$	19.63	19.56	0.99	0.66	0.29	21.64	+1.58
4.15 "	$0^{\circ}.33$	$1^{\circ}.05$	19.64	19.56	0.99	0.66	0.29	21.64	+1.58

Displacement of the manometer = 0.44 mm.

Table XXIV.

Experiment No. 2.											
Original wt. normal concentration of solution, 0.9.											
Rotation of original solution, 98°.40 (<i>t</i> = 18°.5).											
Rotation at conclusion of exp't, 96°.45 (<i>t</i> = 18°.5).											
Loss in rotation, 1°.95 = 1.98 per cent.											
Calibration units of air in manometer, 434.93.											
Time of setting up cell, 3.30 P.M., Dec. 29, 1906.											
Resistance of membrane, 102,000 ohms.											
Initial pressure, 20.66 atmospheres.											
Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.			
Dec. 29											
5.30 P.M.	0°.22	1°.80	20.87								
8.00 "	0°.16	1°.06	19.75								
11.30 "	0°.15	0°.97	19.65	19.58	1.01	0.66	0.30	0.02	21.58	20.05	+ 1.53
Dec. 30											
10.00 A.M.	0°.22	1°.04	19.68	19.61	1.01	0.66	0.30	0.02	21.55	20.05	+ 1.50
1.00 P.M.	0°.22	1°.13	19.68	19.60	1.00	0.66	0.30	0.02	21.56	20.05	+ 1.51
5.00 "	0°.25	1°.19	19.69	19.60	1.00	0.66	0.30	0.02	21.56	20.05	+ 1.51
Displacement of the manometer = 0.05 mm.											

Displacement of the manometer = 0.05 mm.

Original wt. normal concentration of solution, 0.9. Experiment No. 2.
 Rotation of original solution, 98°.40 ($t = 18^\circ.5$). Manometer used, No. 13.
 Rotation at conclusion of exp't, 96°.45 ($t = 18^\circ.5$). Capillary depression, 0.02.
 Loss in rotation, 1°.95 = 1.98 per cent. Cell used, G.
 Calibration units of air in manometer, 434.93. Resistance of membrane, 102,000 ohms.
 Time of setting up cell, 3.30 P.M., Dec. 29, 1906. Initial pressure, 20.66 atmospheres.

Table XXV.

Original wt. normal concentration of solution, 1.0. Experiment No. 1.
 Rotation of original solution, $107^{\circ}.2$ ($t = 23^{\circ}$). Manometer used, No. 21.
 Rotation at conclusion of exp't, $104^{\circ}.3$ ($t = 23^{\circ}$). Capillary depression, 0.02.
 Loss in rotation, $2^{\circ}.9 = 2.71$ per cent. Cell used, G.
 Calibration units of air in manometer, 471.37. Resistance of membrane, 90,000 ohms.
 Time of setting up cell, 3.30 P.M., Dec. 12, 1906. Initial pressure, 23.00 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.			
Dec. 12										
5.00 P.M.	$0^{\circ}.14$	$2^{\circ}.3$								
7.30 "	$0^{\circ}.13$	$0^{\circ}.52$								
11.10 "	$0^{\circ}.12$	$0^{\circ}.44$								
Dec. 13										
10.15 A.M.	$0^{\circ}.16$	$0^{\circ}.44$	18.98	18.95	1.00	0.64	0.46	24.07	22.28	+1.79
12.30 P.M.	$0^{\circ}.18$	$0^{\circ}.59$	19.00	18.96	1.00	0.64	0.46	24.06	22.28	+1.79
4.10 "	$0^{\circ}.18$	$0^{\circ}.68$	18.99	18.94	1.00	0.64	0.46	24.09	22.28	+1.81
8.00 "	$0^{\circ}.20$	$0^{\circ}.72$	19.02	18.97	1.00	0.64	0.46	24.05	22.28	+1.77
11.15 "	$0^{\circ}.24$	$0^{\circ}.75$	19.01	18.96	1.00	0.64	0.46	24.06	22.28	+1.78
Dec. 14										
10.00 A.M.	$0^{\circ}.26$	$0^{\circ}.70$	19.00	18.95	1.01	0.64	0.46	24.06	22.29	+1.77
12.30 P.M.	$0^{\circ}.30$	$0^{\circ}.72$	18.99	18.94	1.01	0.64	0.46	24.08	22.29	+1.79

Displacement of the manometer = 0.23 mm.

Table XXVI.

Time.	Temperature.		Volume of air in manometer.		Atmospheric pressure.	Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.		Liquids in manometer.	Inversion.	Capillary depression.			
Dec. 15											
6.30 P.M.	0°.24	2°.80									
11.30 "	0°.20	1°.00	18.76	18.69	1.00	0.58	0.56	0.02	23.96	22.28	+1.68
Dec. 16											
9.45 A.M.	0°.24	0°.82	18.75	18.69	1.00	0.58	0.56	0.02	23.96	22.28	+1.68
1.00 P.M.	0°.24	0°.83	18.73	18.67	1.00	0.58	0.56	0.02	23.99	22.28	+1.71
6.30 "	0°.24	0°.80	18.73	18.68	1.00	0.58	0.56	0.02	23.97	22.28	+1.69
10.30 "	0°.25	0°.80	18.74	18.68	1.00	0.58	0.56	0.02	23.97	22.28	+1.69
Dec. 17											
10.15 A.M.	0°.25	0°.85	18.73	18.67	1.00	0.58	0.56	0.02	23.99	22.28	+1.71
1.00 P.M.	0°.30	0°.97	18.74	18.67	1.00	0.58	0.56	0.02	23.99	22.29	+1.70
4.00 "	0°.34	0°.96	18.73	18.66	1.00	0.58	0.56	0.02	24.00	22.29	+1.71

Displacement of the manometer = 0.59 mm.

Table XXVII.

Original wt. normal concentration of solution, 1.0. Experiment No. 3.
 Rotation of original solution, $107^{\circ}.2$ ($t = 20^{\circ}.5$). Manometer used, No. 13.
 Rotation at conclusion of exp't, $105^{\circ}.2$ ($t = 20^{\circ}.5$). Capillary depression, 0.02.
 Loss in rotation, $2^{\circ}.0 = 1.87$ per cent. Cell used, A.
 Calibration units of air in manometer, 434.93. Resistance of membrane, 134,000 ohms.
 Time of setting up cell, 4-30 P. M., Jan. 14, 1907. Initial pressure, 16.13 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.			Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.			
Jan. 14.										
6.00 P.M.	$0^{\circ}.22$	$2^{\circ}.60$	26.67							
7-30 "	$0^{\circ}.16$	$1^{\circ}.19$	21.44	21.35						
11.00 "	$0^{\circ}.16$	$1^{\circ}.00$	19.27	19.20						
Jan. 15										
10.15 A.M.	$0^{\circ}.22$	$0^{\circ}.96$	17.80	17.74						
1.00 P.M.	$0^{\circ}.26$	$1^{\circ}.06$	17.80	17.73						
5.00 "	$0^{\circ}.26$	$1^{\circ}.06$	17.78	17.71						
8.00 "	$0^{\circ}.26$	$0^{\circ}.96$	17.75	17.69	1.01	0.65	0.31	23.95	22.29	+1.66
11.30 "	$0^{\circ}.26$	$0^{\circ}.91$	17.72	17.66	1.01	0.65	0.31	23.99	22.29	+1.70
Jan. 16										
10.30 A.M.	$0^{\circ}.26$	$0^{\circ}.69$	17.73	17.69	1.01	0.65	0.31	23.95	22.29	+1.66
1.00 P.M.	$0^{\circ}.26$	$0^{\circ}.80$	17.73	17.68	1.01	0.65	0.31	23.96	22.29	+1.67
3-30 "	$0^{\circ}.26$	$0^{\circ}.80$	17.73	17.68	1.01	0.65	0.31	23.96	22.29	+1.67

Displacement of the manometer = 0.91 mm.

Table XXVIII.—Summary of Results.

Weight normal concentration.	No. of experiment.	Temperature of solution.		Osmotic pressure observed (atmospheres).			Calculated p/tw in mean gas pressure osmotic and to gas temperature, pressure. Atmospheres.	Difference between gas pressure osmotic and to gas temperature, pressure.	Ratio of osmotic pressure. to gas pressure.
		Mean.	Highest.	Lowest.	Mean.	Highest.			
0.1	1	0°.26	0°.36	0°.18	2.42	2.42	2.23	0.19	1.085
"	2	0°.21	0°.26	0°.14	2.44	2.44	2.23	0.21	1.094
"	3	0°.24	0°.38	0°.14	2.37	2.37	2.23	0.14	1.063
"	4	0°.24	0°.38	0°.14	2.38	2.39	2.23	0.15	1.067
0.2	1	0°.22	0°.26	0°.16	4.76	4.77	4.46	0.30	1.067
"	2	0°.30	0°.32	0°.28	4.75	4.76	4.46	0.29	1.065
0.3	1	0°.29	0°.34	0°.18	7.02	7.02	6.69	0.33	1.049
"	2	0°.15	0°.18	0°.14	7.03	7.03	6.68	0.35	1.052
0.4	1	0°.19	0°.22	0°.16	9.29	9.31	8.91	0.38	1.043
"	2	0°.28	0°.33	0°.22	9.26	9.26	8.92	0.34	1.038
"	3	0°.32	0°.34	0°.26	9.30	9.31	8.92	0.38	1.043
"	4	0°.15	0°.16	0°.12	9.25	9.26	8.91	0.34	1.038
0.5	1	0°.26	0°.38	0°.14	11.53	11.56	11.14	0.39	1.035
"	2	0°.23	0°.26	0°.20	11.59	11.61	11.14	0.45	1.040
"	3	0°.14	0°.18	0°.12	11.65	11.65	11.14	0.51	1.046
"	4	0°.20	0°.26	0°.16	11.68	11.69	11.14	0.54	1.048
0.6	1	0°.28	0°.28	0°.16	14.00	14.02	13.37	0.63	1.047
"	2	0°.21	0°.25	0°.20	13.97	13.98	13.37	0.60	1.045
0.7	1	0°.26	0°.32	0°.16	16.47	16.48	15.60	0.87	1.056
"	2	0°.15	0°.16	0°.14	16.55	16.56	15.60	0.95	1.061
0.8	1	0°.20	0°.26	0°.16	18.93	18.96	17.82	1.11	1.062
"	2	0°.24	0°.26	0°.16	18.89	18.91	17.83	1.06	1.059
0.9	1	0°.32	0°.33	0°.30	21.64	21.64	20.06	1.58	1.079
"	2	0°.21	0°.25	0°.15	21.56	21.58	20.05	1.51	1.075
1.0	1	0°.22	0°.30	0°.16	24.07	24.09	22.28	1.79	1.080
"	2	0°.26	0°.34	0°.20	23.98	24.00	22.28	1.70	1.076
"	3	0°.26	0°.26	0°.26	23.96	23.99	22.29	1.67	1.075

Table XXIX.—Mean Values for Each Concentration.

Weight-normal concentration.	Temperature.	Observed osmotic pressure. Atmospheres.	Calculated gas pressure. Atmospheres.	Difference between osmotic and gas pressures. Atmospheres.	Ratio of osmotic to gas pressure.
0.1	0°.24	2.40	2.23	0.17	1.077
0.2	0°.26	4.76	4.46	0.30	1.067
0.3	0°.22	7.03	6.69	0.34	1.051
0.4	0°.24	9.28	8.92	0.36	1.040
0.5	0°.21	11.61	11.14	0.47	1.042
0.6	0°.22	13.99	13.37	0.62	1.046
0.7	0°.21	16.51	15.60	0.91	1.058
0.8	0°.22	18.99	17.83	1.08	1.060
0.9	0°.27	21.60	20.06	1.54	1.077
1.0	0°.25	24.00	22.28	1.72	1.077

The individual experiments in this series of measurements of the osmotic pressure of cane-sugar solutions are given in the Tables from I. to XXVII. All the essential data have been given except the actual readings with the telescope. For convenience of examination and comparison, the results have been brought together in Table XXVIII., the number of experiments made for each concentration being given.

Loss in Rotation.

Tables I. to XXVII. show that every solution suffered some loss in rotation while in the cell, and this has been recorded in the tables as due to the *inversion* of the cane-sugar. This loss in rotation of the solution in the cell by far exceeds that which takes place in the same time in an identical solution, which has not been enclosed in the cell. It cannot be possible that all of this loss in rotation is due simply to inversion, but a portion of it, and very probably a considerable portion of it, results from a dilution of the cell contents, which occurs while the cell is being closed at the beginning, and opened at the end of an experiment. The amount of dilution has been considerably diminished, due to the skill and rapidity which the operators have acquired in the processes of closing and opening the cells. The former can now be accomplished in

about eight minutes, while the latter requires only about two to three minutes.

When the cell is being opened, the contents are under considerably diminished pressure most of the time and necessarily suck in water from the cell wall. During the process of closing the cell, previous to a measurement, a similar dilution takes place. Formerly, the operations of closing and opening the cells required for each 15 to 20 minutes. A further dilution takes place, due to the slipping of the manometer upward through the rubber stopper. By methods described above, this last difficulty has been overcome in a great measure. Table XXX., column 3, will show that this slipping of the manometer was very slight. It is very important to overcome such movements of the manometer or crowding upwards of the manometer and stopper under the pressure of the cell contents, either of which movements would increase the capacity of the cell and necessarily bring about a dilution of the solution within:

Table XXX.

Weight-normal concentration.	Number of experiment.	Upward movement of manometer. mm.	Loss in rotation.		Correction for inversion.
			Degrees.	Percentage.	
					Atmosphere.
0.1	1	0.07	0.20	1.60	0.03
"	2	0.07	0.10	0.80	0.01
"	3	0.09	0.05	0.39	0.01
"	4	0.09	0.10	0.79	0.01
0.2	1	0.05	0.15	0.61	0.02
"	2	0.05	0.15	0.60	0.02
0.3	1	0.06	0.50	1.37	0.07
"	2	0.06	0.60	1.64	0.08
0.4	1	0.08	0.55	1.15	0.08
"	2	0.07	0.60	1.25	0.08
"	3	0.22	0.40	0.83	0.06
"	4	0.04	0.40	0.83	0.06
0.5	1	0.24	0.90	1.53	0.13
"	2	0.22	1.00	1.70	0.14
"	3	0.07	1.05	1.71	0.15
"	4	0.38	0.75	1.29	0.11
0.6	1	0.48	1.20	1.73	0.12
"	2	0.10	1.30	1.86	0.14

Table XXX.—Continued.

Weight normal concentration.	Number of experi- ment.	Upward movement of manometer. mm.	Loss in rotation.		Correction for inver- sion.
			Degrees.	Percentage.	
Atmosphere.					
0.7	1	0.61	1.20	1.51	0.18
"	2	0.45	1.10	1.39	0.16
0.8	1	0.01	1.55	1.74	0.23
"	2	0.34	1.60	1.80	0.24
0.9	1	0.44	1.85	1.88	0.29
"	2	0.05	1.95	1.98	0.30
1.0	1	0.23	2.90	2.71	0.46
"	2	0.59	3.50	3.26	0.56
"	3	0.91	2.00	1.87	0.31
(1)	(2)	(3)	(4)	(5)	(6)

When the mercury rises in the manometer, a slight increase in the capacity of the cell follows, but this is so small that it may be overlooked, as when the cell is first set up the brass nut is screwed down tightly upon the rubber stopper, at intervals, until the mercury has nearly reached its maximum height.

It has been stated¹ that the dilution is not due to leakage of the solution through the membrane. If this was the case, the membranes would not have the ability, as they do, to maintain for long periods, undiminished, the maximum pressures which the solutions have, under any conditions, been found to exert. It has been found that pressures obtained with leaky membranes are inconstant and somewhat low. A constant pressure may be exhibited for a considerable length of time, but after some hours, it will begin to decline. Sometimes the rupture in the membrane will appear to have been repaired by the membrane-forming salts which are always present, and the mercury in the manometer will again begin to rise but it will usually not reach its former height. This is due to the cell contents being diluted slightly by taking in water through the rupture before it was mended. This behavior of cells with leaky membranes will be repeated over and over again until the membrane is brought into good con-

¹ Am. Chem. J., 36, 32, 43.

dition. The reason why the mercury in the manometer is able to remain almost at a constant level for a considerable time, notwithstanding there is a slight rupture in the membrane, is that the intake of water and the escape of the solution are temporarily in equilibrium.

In Table XXX. are brought together all of the losses of rotation which the solutions suffered while in the cells. They are stated in the form of saccharimeter degrees in column 4, and in percentages of original rotation in column 5. It is impossible to ascertain, with any degree of certainty, just what proportion of the loss in rotation is to be ascribed to inversion and how much to dilution. It is of the greatest importance that an accurate estimation be made as to how the loss in rotation of the solutions distributes itself between the inversion and the dilution, as the correction for inversion, when applied to the observed pressure, lowers it, while that for dilution raises it; that is to say, the two corrections are of a compensating character. But an *absolutely accurate* estimation by the methods now in use is impossible.

In order to form an approximate idea of the effect of this loss in rotation, tables have been prepared to which reference will now be made. In column 6 of Table XXX. are given, in fractions of an atmosphere, the corrections for each experiment, if all the observed loss in rotation is ascribed to inversion and no allowance is made for dilution. These results are, without doubt, somewhat too low, as some of the loss in rotation must have been due to dilution, the correction for which would be added to the observed pressures, if it could be applied.

Table XXXI.—Corrections for Inversion and Dilution.

Weight-normal concentration.	No. of experiment.	Calculated gas pressure.	Osmotic pressure.		
			1. If all loss in rotation is ascribed to invers'n.	2. If all loss in rotation is ascribed to dilution.	3. If half the loss in rotation is ascribed to dilution.
0.1	1	2.23	2.42	2.51	2.48
"	2	2.23	2.44	2.48	2.46
"	3	2.23	2.37	2.39	2.39
"	4	2.23	2.38	2.42	2.41
0.2	1	4.46	4.76	4.83	4.80
"	2	4.46	4.75	4.81	4.79
0.3	1	6.69	7.02	7.20	7.14
"	2	6.68	7.03	7.25	7.18
0.4	1	8.91	9.29	9.49	9.43
"	2	8.92	9.26	9.47	9.40
"	3	8.92	9.30	9.45	9.41
"	4	8.91	9.25	9.40	9.35
0.5	1	11.14	11.53	11.84	11.75
"	2	11.14	11.59	11.96	11.85
"	3	11.14	11.65	12.03	11.91
"	4	11.14	11.68	11.96	11.87
0.6	1	13.37	14.00	14.39	14.25
"	2	13.37	13.97	14.40	14.25
0.7	1	15.60	16.47	16.92	16.78
"	2	15.60	16.55	16.97	16.83
0.8	1	17.82	18.93	19.52	19.34
"	2	17.83	18.89	19.51	19.32
0.9	1	20.06	21.64	22.37	22.15
"	2	20.05	21.56	22.33	22.10
1.0	1	22.28	24.07	25.23	24.87
"	2	22.28	23.98	25.41	24.98
"	3	22.29	23.96	24.74	24.50
(1)	(2)	(3)	(4)	(5)	(6)

In Table XXXI. the corrections for loss in rotation are applied in three different ways and the results of the individual experiments are given:

1. If all loss in rotation is ascribed to inversion and no correction is made for dilution (column 4).
2. If all loss in rotation is ascribed to dilution and no correction is made for inversion (column 5).
3. If one-half the observed loss in rotation is ascribed to dilution and no correction is made for inversion (column 6).

The mean values of each concentration are presented in the same manner in Table XXXII:

Table XXXII.—Mean Value for Each Concentration.

Weight-normal concentration.	Temperature.	Calculated gas pressure.	Osmotic pressure.		
			1. If all loss in rotation is ascribed to invers'n.	2. If all loss in rotation is ascribed to dilution.	3. If half the loss in rotation is ascribed to dilut'n.
0.1	0°.24	2.23	2.40	2.45	2.44
0.2	0°.26	4.46	4.76	4.82	4.80
0.3	0°.22	6.69	7.03	7.23	7.16
0.4	0°.24	8.92	9.28	9.45	9.40
0.5	0°.21	11.14	11.61	11.95	11.85
0.6	0°.22	13.37	13.99	14.40	14.25
0.7	0°.21	15.60	16.51	16.95	16.81
0.8	0°.22	17.83	18.99	19.52	19.33
0.9	0°.27	20.06	21.60	22.35	22.13
1.0	0°.25	22.28	24.00	25.13	24.78
(1)	(2)	(3)	(4)	(5)	(6)

As the results given in column 4 are too low on account of no correction being made for *dilution*, so are those in column 5 too high, because no correction is made for *inversion*.

The method of Fehling has been used to determine the amount of inversion which takes place in the cell, but without convincing results. The maximum inversion, even in weight-normal solutions, which has been detected by this method, has not exceeded the quantity, which, as a correction for observed pressures, would be equivalent to 0.05 atmosphere.

In column 6 of Tables XXXI. and XXXII. are given the pressures for the various weight-normal concentrations of the solutions as they would stand if the observed pressures were corrected by ascribing one-half the loss in rotation to dilution and making no correction for inversion. These values are, in all probability, about correct, but if they vary in either direction, they are thought to be still somewhat high. The reason for this belief is, that when the cell is being opened a certain amount of dilution takes place, due to the diminished pressure upon the contents of the cell, which dilution does not affect the observed pressure, while that in closing the

cell does. Hence, the correction for the dilution which takes place in the latter case, alone should be applied. It is impossible though to estimate the amount of this. When the cell is being closed it is not under diminished pressure as it is when being opened, and probably a larger portion of the dilution takes place subsequent to the measurement of the pressure than was brought about during the closing of the cell. Still, more time is required to close a cell than to open one, and dilution that occurs during this longer period of time may compensate for that which is caused by the diminished pressure in the process of opening it.

In view of the above facts, it is believed to be a fair approximation if one-half the observed loss of rotation be deducted before correcting the observed pressure for dilution. If cells could be devised in which no dilution can take place, pressures would very probably be found for the various concentrations which would lie between those recorded in columns 4 and 6 of Tables XXXI. and XXXII. It is supposed then that the measurements as presented in column 4 of the tables are till uncertain³ only within the limits indicated below:

Weight-normal concentration.	Limit of uncertainty	
	Atmosphere.	Percentage.
0.1	0.04	1.66
0.2	0.04	0.84
0.3	0.13	1.85
0.4	0.12	1.29
0.5	0.24	2.07
0.6	0.26	1.86
0.7	0.30	1.82
0.8	0.34	1.79
0.9	0.53	2.45
1.0	0.78	3.25

Methods of overcoming this loss in rotation of the solutions have been most carefully considered. The element of time consumed in the processes of opening and closing the cells seems to affect this to a very marked degree. It shows that the loss in rotation is affected to a greater extent by any unusual prolongation or shortening of the time employed in opening than in closing the cells.

In order to ascertain whether a considerable portion of the loss in rotation is due to dilution rather than to inversion, the cells, just before they were closed, and again just before they were opened, were dipped in a solution of sugar whose concentration was the same as that of the solution under investigation. In all such cases the loss in rotation was much less than that of solutions in cells which had not been so treated, provided no unusually long time was consumed in the closing and opening processes. The cells, after having been dipped, were carefully cleansed externally with distilled water before they were put into the bath.

Conclusions.

The most important fact that has been brought out by this series of measurements is that the osmotic pressure of cane-sugar solutions, in the vicinity of the freezing point of water, considerably exceeds the calculated gas pressures for the same temperatures. In order to facilitate a comparison of the two sets of values, Tables XXXIII. and XXXIV. have been introduced. In these tables the ratios of the osmotic to gas pressures are given in three ways (columns 4, 5 and 6), according to each of the possible methods of correcting the observed pressures for the loss in rotation which occurs in the cell. The fact of an excess of osmotic over gas pressure at such low temperatures appears to be established, whatever may be the view which is accepted as to the proper method of correcting the observed pressures for loss in rotation.

A satisfactory explanation of this excess of osmotic over gas pressure of cane sugar solutions in the vicinity of 0° has not yet been reached. Some may see an evidence of hydration of the cane sugar in solution, and may support their views by referring to the abnormal lowering of the freezing points of such solutions.

Table XXXIII.

Weight-normal concentration.	No. of experiment.	Calculated gas pressure.	Ratio of osmotic to gas pressure.		
			1. If all loss in rotation is ascribed to inversion.	2. If all loss in rotation is ascribed to dilution.	3. If half the loss in rotation is ascribed to dilut'n.
0.1	1	2.23	1.085	1.126	1.112
"	2	2.23	1.094	1.112	1.103
"	3	2.23	1.063	1.072	1.072
"	4	2.23	1.067	1.085	1.081
0.2	1	4.46	1.067	1.083	1.076
"	2	4.46	1.065	1.078	1.074
0.3	1	6.69	1.049	1.076	1.067
"	2	6.68	1.052	1.085	1.075
0.4	1	8.91	1.043	1.065	1.058
"	2	8.92	1.038	1.062	1.054
"	3	8.92	1.043	1.059	1.055
"	4	8.91	1.038	1.055	1.049
0.5	1	11.14	1.035	1.063	1.055
"	2	11.14	1.040	1.074	1.064
"	3	11.14	1.046	1.080	1.069
"	4	11.14	1.048	1.074	1.066
0.6	1	13.37	1.047	1.076	1.066
"	2	13.37	1.045	1.077	1.066
0.7	1	15.60	1.056	1.085	1.076
"	2	15.60	1.061	1.088	1.079
0.8	1	17.82	1.062	1.095	1.085
"	2	17.83	1.059	1.094	1.084
0.9	1	20.06	1.079	1.115	1.104
"	2	20.05	1.075	1.114	1.102
1.0	1	22.28	1.080	1.132	1.116
"	2	22.28	1.076	1.140	1.121
"	3	22.29	1.075	1.110	1.099
(1)	(2)	(3)	(4)	(5)	(6)

The results in Table XXXIII. are further summarized in Table XXXIV., the average of the values for each concentration being given:

Table XXXIV.—Mean Values for Each Concentration.

Weight-normal concentration.	Temperature.	Calculated gas pressure.	Ratio of osmotic to gas pressure.		
			1. If all loss in rotation is ascribed to invers'n.	2. If all loss in rotation is ascribed to dilution.	3. If half the loss in rotation is ascribed to dilution.
0.1	0°.24	2.23	1.077	1.099	1.092
0.2	0°.26	4.46	1.067	1.081	1.075
0.3	0°.22	6.69	1.051	1.081	1.071
0.4	0°.24	8.92	1.040	1.060	1.054
0.5	0°.21	11.14	1.042	1.073	1.064
0.6	0°.22	13.37	1.046	1.077	1.066
0.7	0°.21	15.60	1.058	1.087	1.078
0.8	0°.22	17.83	1.060	1.095	1.085
0.9	0°.27	20.06	1.077	1.115	1.103
1.0	0°.25	22.28	1.077	1.127	1.112
(1)	(2)	(3)	(4)	(5)	(6)

By a comparison of the pressures obtained at the low temperatures with those which were obtained in the vicinity of 20°, it will be noticed that they are in a general way almost the same. This may lead to the suggestion that osmotic pressure, unlike gas pressure, *has little or no temperature coefficient*. But an equally just assumption may be made that somewhere between 0° and 20°, a temperature may be found at which osmotic pressure, like the volume of the solvent, is at a *minimum*, and from which it will increase with change of temperature in both directions.

In this series of measurements a peculiarity appears to which attention should be called. This may be most easily seen by referring to columns 4, 5 and 6 of Table XXXIV. It will be seen there that the ratio of osmotic to gas pressure appears to reach a minimum with the 0.4 weight-normal solution. When this was first observed it was thought that perhaps some error might have been made in measuring the pressures of certain concentrations, hence a larger than usual number of measurements were made of the 0.1, 0.4 and 0.5 normal solutions. But the same results were obtained as at first. The reality of this apparent minimum ratio is not regarded as established. The reasons for this doubt have been given elsewhere.¹

¹ Am. Chem. J., 36, 33; 37, 466.

BIOGRAPHY.

William W. Holland was born at Eastville, Northampton Co., Virginia, September 18, 1881. He received his early training under private tutors and at Eastville Academy. In 1900 he entered the University of Virginia, where he remained for four years, pursuing principally the scientific courses of study. In 1904 he entered the Johns Hopkins University for the study of chemistry. The summer of 1905 he spent at the University of Chicago, and in 1906 received the degree of Bachelor of Arts from Central University. In 1906-1907 he held a Virginia scholarship at Hopkins. His principal subject was Chemistry, subordinate subjects being Physical Chemistry and Mineralogy.

